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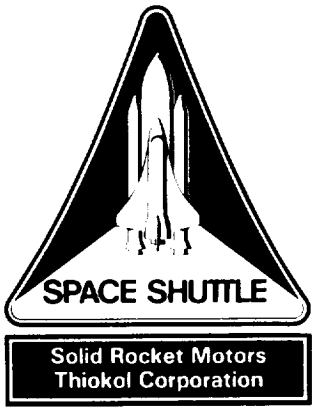

TWR-17552-10

RSRM-13 (360Q013) FINAL REPORT BALLISTICS MASS PROPERTIES FLIGHT DESIGNATION STS-41

11 December 1990

Prepared for:

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ECS SS-1021

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1.0 INTRODUCTION

This report contains the propulsion performance and reconstructed mass properties data from Thiokol's RSRM-13 motors which were assigned to the STS-41 launch. The Thiokol manufacturing designations for the motors were 360Q013A/360Q013B, which are referred to in this report as RSRM-13A and RSRM-13B, respectively. The flight set is designated as 360Q013 due to both motors being a quarterweight. The launch occurred on 6 October 1990 at the Eastern Test Range (ETR). The data contained herein was input to the STS-41 Flight Evaluation Report.

The SRM propellant, TP-H1148, is a composite type solid propellant, formulated of polybutadiene acrylic acid acryonitrile terpolymer binder (PBAN), epoxy curing agent, ammonium perchlorate oxidizer and aluminum powder fuel. A small amount of burning rate catalyst (iron oxide) was added to achieve the desired propellant burn rate. The propellant evaluation and raw material information for the RSRM-13 motors are included in the discussion section of this report.

The propellant grain design consists of four segments. There is a forward segment with an eleven point star with a transition into a tapered circular perforated (CP) configuration. There are two center segments that result in a double tapered CP configuration and an aft segment with a triple taper CP configuration and a cutout for the partially submerged nozzle (Figure 1.1).

The ballistic performance presented in this report was based on the Operational Flight Instrumentation (OFI). The adjustments made to the raw data on this flight include biasing the data to correct ambient pressure before liftoff. This was done in response to suggestions from the OPT technical interchange meeting held the 5th and 6th of April 1990.

The data used for the reconstruction of the left hand motor was the average of the 1 and 5 sample/sec gauges. The right motor used the 5 sample/sec data. The raw data for each gauge was corrected to read the ambient pressure of 14.77 psia prior to ignition. In addition, the data for both motors was adjusted up by 1% from 0 to 1 seconds and the ramped down from 1.0% to 0.4% from 1-2 seconds and then adjusted up 0.4% thereafter. These adjustments are a result of a bias between the OPT and Taber pressure transducers which are used on flights and static tests respectively. No high sample rate pressure gauges, Development Flight Instrumentation (DFI), were used on this flight and therefore no ignition data will be presented.

2.0 SUMMARY

The delivered propellant burn rates were close to predicted. The delivered burn rates were 0.366 and 0.365 in/sec at 625 psia and 60°F for the left and the right RSRM's respectively. The predicted burn rates were 0.366 in/sec for both left and right motors respectively. The performance of the two motors was very close as can be seen in Figure 2.1.

The performance of the pair of motors were compared to the following CEI Specification CPW1-3600A paragraphs for compliance: 3.2.1 Performance, 3.2.1.1 General Performance, 3.2.1.1.2 Motor Characteristics, 3.2.1.1.2.1 Nominal Thrust Time Curve, 3.2.1.1.2.2 Performance Tolerance and Limits, 3.2.1.1.2.4 Impulse Gates and 3.2.1.1.2.3 Thrust Differential. The aspects of the CEI Specification that could not be compared due to low sampling of the data were 3.2.1.1.1 Ignition Characteristics, 3.2.1.1.1.1 Ignition Interval and 3.2.1.1.1.2 Pressure Rise Rate. The performance from each motor as well as matched pair performance values were well within the CEI Specification requirements. The nominal thrust time curve and impulse gate information has been included. The historical average was well within the variation

limits developed from the RSRM Block prediction population at a burn rate of 0.368 in/sec at 625 psia and 60°F. The historical population values are the average performance data from DM-8, DM-9, QM-6, QM-7, QM-8, PVM-1, RSRM-1, RSRM-2, RSRM-3, RSRM-4A, RSRM-5 through RSRM-10A, and RSRM-13A.

Post flight reconstructed RSRM mass properties are within expected values for the RSRM lightweight (RSRML) configurations and meet the following CEI paragraphs:3.2.2.2, 3.2.2.2.1, 3.2.2.2.2, and 3.2.2.2.3.

3.0 DISCUSSION AND RESULTS

3.1 RSRM-13 PROPELLANT MATERIALS

Both of the thirteenth flight motors were cast with primarily one evaluation of propellant, F72. An evaluation is defined as a specific combination of raw material lots and all of the standardization and production batches of propellant produced with these materials. There were however, 2 verification mixes of evaluation G24 in the left motor forward center segment and 2 verification mixes from the same evaluation in the left aft segment. In addition to the verification mixes, the right motor aft segment was replaced with the RSRM-10B aft segment which was cast from Evaluation F66. Table 3.1 shows the raw material lots and vendors for the evaluations used. The igniters used in this flight set were cast from propellant evaluation G43, mix G430002. See document TWR-19070 for more information on propellant materials for this flight set. For more information on this lot of igniters see lot acceptance test (LAT) 42 test report (TWR-60180).

3.2 RSRM PROPULSION PERFORMANCE ANALYSIS

All times shown in this section, unless noted otherwise are referenced to the RSRM ignition command time at 90:279:11:47:14:983(GMT). As previously mentioned the OFI data was used for the steady state and tailoff performance assessment.

The ballistic performance was reconstructed using SCB04 steady state 1-D mass addition computer program, and SCA08 SRM modeling program. Both

computer codes have been consistently used for predictions as well as reconstructions throughout the SRM program. Since thrust was not measured on the flight motors, average values of η_r's and C_m's, which are used for the pressure to thrust conversion, were taken from RSRM static test motors and applied to the measured head end pressure to determine the thrust values.

3.3 RSRM DELIVERED PERFORMANCE

3.3.1 RSRM-13A/RSRM-13B Thrust and Pressure Comparison

The flight motor reconstructed thrust-time traces at the delivered temperature of 82°F are shown in Figure 2.1. A comparison between the predicted thrust and reconstructed thrust for each motor can be seen in Figures 3.1, 3.2.

The comparison of predicted and measured head end chamber pressure is shown in Figures 3.3, 3.4.

Figures 3.5 and 3.6 show how RSRM-13A and RSRM-13B compared with a nominal performance average for the RSRM at standard conditions of 0.368 burn rate and 60 °F PMBT.

3.3.2 RSRM Predicted Impulse, ISP, Burn Rate, Event Times, Separation, and PMBT Comparison

The reconstructed RSRM-13 propulsion performance at delivered conditions is compared to the predicted performance in Table 3.2. The actual values were very close to the predicted data for both motors.

The predicted scale factor of 1.0175 for conversions from 5 inch CP burn rates to actual motor burn rate were based on an average scale factor from the HPM-RSRM population. The actual scale factors for left and right motors were 1.0187 and 1.0150 respectively.

The propellant mean bulk temperature (PMBT) used in the Ballistics reconstruction for both motors was 82°F. This was based on predicted 2-D temperature gradients expected in the RSRMs. Table 3.3 shows the predicted gradient (data provided by 3-D SINDA Model Aero-Thermal Group).

3.4 CEI SPECIFICATION PERFORMANCE REQUIREMENTS

3.4.1 Performance Tolerances

The parameter variations of the total population of RSRMs about a nominal value are constrained by the requirements defined in the CEI Specification paragraph 3.2.1.1.2.2, Table II. A comparison of the RSRM-13A and RSRM-13B calculated and reconstructed parameters at PMBT of 60°F with respect to the nominal values and the CEI Specification maximum 3 sigma requirements is shown in Tables 3.4 and 3.5. All values are within CEI specification requirements.

3.4.2 RSRM Nominal Thrust-Time Performance

The nominal RSRM performance is defined as the average performance of the RSRM static test and flight motor series at standard conditions. The standard conditions consist of the propellant burn rate of 0.368 in/sec at 625 psia and a PMBT of 60°F. The flight motor reconstructed thrust-time traces are normalized to standard conditions and averaged with past RSRM flight and static test data at standard conditions to form the RSRM population nominal thrust-time trace. This nominal RSRM performance will be continually updated during the Shuttle program. It is the current estimate of the RSRM population nominal. The nominal performance for the thrust time trace and impulse gate requirements is based on the performance of DM-8, DM-9, QM-6, QM-7, QM-8, PVM-1, RSRM-1, RSRM-2, RSRM-3, RSRM-4A, RSRM-5 through RSRM-10A, and RSRM-13A. The delivered RSRM population nominal performance is compared to the CEI Specification paragraph 3.2.1.1.2.1, Table I requirements on Figure 3.7.

3.4.3 Impulse at Standard Conditions VS. Requirement Gates

The vacuum impulse at standard conditions at each of the gates is compared to the CEI Specification paragraph 3.2.1.1.2.4 requirements in Table 3.6. The population making up the standard nominal for the impulse requirements are the same as those in the nominal thrust time trace (Figure 3.7).

3.4.4 Matched Pair Thrust Differential

The maximum thrust imbalance assessment is shown in Table 3.7. Figure 3.8 shows the thrust differential during steady state and tail off. All the thrust differential values were near the nominal values experienced by previous flight SRMs and were well within the CEI Specification paragraph 3.2.1.1.2.3, Table III limits. The thrust values used for the assessment were reconstructed at the delivered conditions of each motor. Thrust imbalance was a concern due to the aft segment replacement. A waiver was written regarding possible thrust imbalance excedance but the actual imbalance was minimal.

3.4.5 Matched Pair Performance Requirements

The CEI Specification requires that a matched pair of motors on a flight set have similar performance at delivered conditions according to Table 3.8. The RSRMs for STS-41 were well within the matched pair specification requirements.

3.5 RECONSTRUCTED MASS PROPERTIES

The Thiokol manufacturing designation, 360Q013, along with RSRM-13 have been used, by Mass Properties, to identify the RSRMs used on this flight. Tables 3.9 and 3.10 provide RSRM-13A and RSRM-13B reconstructed sequential mass properties, respectively.

Table 3.11 and 3.12 compares RSRML predicted sequential weight and center of gravity (cg) data against post flight reconstructed data. A 2,000 lbm slag weight was used for both pre-fire and post-fire sequential predictions. Actual 360Q013 mass properties may be obtained from Mass Properties History Log Space Shuttle 360Q013A-LH (TWR-17358, Rev B), dated 24 October 1990, and 360W013B-RH (TWR-17359, Rev A), dated 24 October 1990. Some of the mass properties data used has been taken from average actual data presented in the 5 March 1990 Mass Properties Quarterly Status Report(TWR-10211-94). Postflight reconstructed data reflects Ballistics mass flow data from the 12.5 sample per second measured pressure traces and a predicted slag weight of 2,000 lbm.

Table 3.13 and 3.14 presents CEI requirements, predicted, and actual weight comparisons. The actual weights are in close agreement with predicted values. Mass Properties data for both RSRMs comply with CEI requirements.

TABLE 3.1 RAW MATERIAL EVALUATION SUMMARY

TP-H1148 PROPELLANT EVALUATION	INGREDIENT	STOCK-LOT	VENDOR
F66	HB Polymer	7227-0074	ASRC
	ECA	7225-0082	Dow Chemical
	Aluminum	7228-0071	Alcoa
	Iron Oxide	7226-0026	Charles Pfizer
	AP unground	7229-0086	Kerr McGee
	AP ground	7229-0086	Kerr McGee
	HB/ECA Ratio	86.6% HB	
	Iron Oxide	0.257%	
F72	HB Polymer	7227-0077	ASRC
	ECA	7225-0090	Dow Chemical
	Aluminum	7228-0078	Reynolds
	Iron Oxide	7226-0026	Charles Pfizer
	AP unground	7229-0092	Kerr McGee
	AP ground	7229-0092	Kerr McGee
	HB/ECA Ratio	86.3% HB	
	Iron Oxide	0.259%	
G24	HB Polymer	7227-0085	ASRC
	ECA	7225-0094	Dow Chemical
	Aluminum	7228-0082	Reynolds
	Iron Oxide	7226-0029	Charles Pfizer
	AP unground	7229-0094	Kerr McGee
	AP ground	7229-0094	Kerr McGee
	HB/ECA Ratio	86.5% HB	
	Iron Oxide	0.264%	

TABLE 3.2 RSRM-13 PROPULSION PERFORMANCE ASSESSMENT

	(LEFT MOTOR 82 DEG) PREDICTED	ACTUAL	(RIGHT MOTOR 82 DEG) PREDICTED	ACTUAL
IMPULSE GATES				
I-20 (10^6 lbf sec)	65.84	66.08	66.06	66.31
I-60 (10^6 lbf sec)	175.47	175.07	175.95	175.53
I-AT (10^6 lbf sec)	297.46	296.77	297.47	296.82
VACUUM ISP (lbf*sec/lbm)	268.64	268.02	268.64	268.05
BURN RATE (in/sec)	0.3655	0.3659	0.3663	0.3654
EVENT TIMES (sec) *				
IGNITION INTERVAL	N/A	N/A	N/A	N/A
WEB TIME *	109.68	109.19	109.32	109.99
TIME OF 50 PSIA CUE	119.29	118.90	118.92	118.94
ACTION TIME *	121.37	121.23	121.00	121.60
SEPARATION COMMAND (sec)	124.19	123.84	124.19	123.84
PMBT (deg F)	82.0	82.0	82.0	82.0
MAXIMUM IGNITION RISE RATE (psia/10 ms)	91.9	N/A	91.9	N/A
DECAY TIME (sec) (59.4 psia to 85 K)	2.8	3.0	2.7	3.4

TAILOFF IMBALANCE IMPULSE DIFFERENTIAL (KLBF-SEC)	PREDICTED	ACTUAL
	N/A	352.8

Impulse Imbalance = Left Motor - Right Motor

* All times are referenced to ignition command time except where noted by an *. These times are referenced to lift off time (ignition interval).

TABLE 3.3
PREDICTED PROPELLANT
TEMPERATURE GRADIENTS IN RSRM-13

DISTANCE FROM OUTSIDE SURFACE OF CASE (IN.)	15	45	75	105	135	165	195	225	255	285	315	345
0.0 CASE SURFACE	80.53	80.54	80.57	80.59	80.81	81.21	81.68	82.03	82.11	81.86	81.26	81.73
0.25 STEEL CASE	80.53	80.54	80.57	80.59	80.81	81.21	81.68	82.03	82.11	81.86	81.26	81.73
1,094 PROPELLANT	81.01	81.03	81.09	81.14	81.33	81.66	82.05	82.36	82.44	82.21	81.68	81.19
6.114 PROPELLANT	81.34	81.41	81.52	81.62	81.79	81.99	82.24	82.45	82.50	82.32	81.88	81.49
13.130 PROPELLANT	81.37	81.44	81.59	81.72	81.87	82.02	82.18	82.32	82.37	82.20	81.83	81.49
21.550 PROPELLANT	81.40	81.45	81.57	81.71	81.84	81.97	82.10	82.23	82.25	82.11	81.79	81.50
29.970 PROPELLANT	81.54	81.57	81.68	81.81	81.93	82.05	82.15	82.26	82.27	82.15	81.87	81.63
38.390 PROPELLANT	81.67	81.69	81.78	81.91	82.03	82.13	82.22	82.32	82.33	82.21	81.97	81.75

TABLE 3.4

COMPARISON OF RSRM-13A VARIATIONS AT PMBT = 60°F ABOUT THE NOMINAL TO THE CEI SPECIFICATION REQUIREMENTS

PARAMETER	CEI MAX 3 SIGMA VARIATION% (1)	NOMINAL VALUE (2)	RSRM-13A VALUE (3)	RSRM-13A VARIATION % (4)
WEB TIME	±5.0	111.1	111.78	0.61
ACTION TIME	±6.5	123.2	124.05	0.69
WEB TIME AVG PRESSURE	±5.3	664.8	659.10	- 0.86
MAX PRESSURE	±6.5	914.2	907.83	- 0.70
MAX SEA LEVEL THRUST	±6.2	3.07	3.052	- 0.58
WEB TIME AVG VAC THRUST	±5.3	2.60	2.581	- 0.75
VAC DEL SPECIFIC IMPULSE	±0.7	268.4	267.80	- 0.22
WEB TIME VAC TOTAL IMPULSE	±1.0	289.2	288.45	- 0.26
ACTION TIME TOTAL IMPULSE	±1.0	296.9	296.35	- 0.19

PRESSURE VALUES IN PSIA, THRUST VALUES IN MLBF,
IMPULSE VALUES IN MLBF-SEC
TIME VALUES IN SECONDS

(1) CEI PARAGRAPH 3.2.1.1.2.2, TABLE II

(2) DM-8, DM-9, QM-6, QM-7, QM-8, PVM-1, RSRM-1 thru RSRM-4A AVERAGE AT STANDARD CONDITIONS.

(3) RSRM-13A AT PMBT = 60°F

(4) VARIATION = ((RSRM-13A - NOMINAL)/NOMINAL)*100

TABLE 3.5

COMPARISON OF RSRM-13B VARIATIONS AT PMBT = 60°F ABOUT THE NOMINAL TO THE CEI SPECIFICATION REQUIREMENTS

PARAMETER	CEI MAX 3 SIGMA VARIATION% (1)	NOMINAL VALUE (2)	RSRM-13B VALUE (3)	RSRM-13B VARIATION % (4)
WEB TIME	±5.0	111.1	112.57	1.33
ACTION TIME	±6.5	123.2	124.38	0.96
WEB TIME AVG PRESSURE	±5.3	664.8	656.60	- 1.23
MAX PRESSURE	±6.5	914.2	918.10	0.43
MAX SEA LEVEL THRUST	±6.2	3.07	3.055	- 0.48
WEB TIME AVG VAC THRUST	±5.3	2.60	2.571	- 1.12
VAC DEL SPECIFIC IMPULSE	±0.7	268.4	267.83	- 0.21
WEB TIME VAC TOTAL IMPULSE	±1.0	289.2	289.41	0.07
ACTION TIME TOTAL IMPULSE	±1.0	296.9	296.38	- 0.17

PRESSURE VALUES IN PSIA, THRUST VALUES IN MLBF,
IMPULSE VALUES IN MLBF-SEC
TIME VALUES IN SECONDS

(1) CEI PARAGRAPH 3.2.1.1.1, TABLE II

(2) DM-8, DM-9, QM-6, QM-7, QM-8, PVM-1, RSRM-1 thru RSRM-4A AVERAGE AT STANDARD CONDITIONS.

(3) RSRM-13B AT PMBT = 60 F

(4) VARIATION = ((RSRM-13B - NOMINAL)/NOMINAL)*100

TABLE 3.6

RSRM-HPM POPULATION IMPULSE GATES

IMPULSE (3)	REQUIREMENT (1)	STANDARD NOMINAL (2)
Impulse at 20 sec (10**6 LBF-SEC)	63.1 (MIN)	64.8
Impulse at 60 sec (10**6 LBF-SEC)	171.2 - 178.1 172.9 (+3%,-1%)	173.0
Impulse at ACTION TIME (10**6 LBF-SEC)	293.8 (MIN)	296.8

(1) CEI PARAGRAPH 3.2.1.1.2.4

(2) NORMALIZED TO STANDARD CONDITIONS-BURN RATE OF 0.368 IN/SEC. POPULATION IS SAME AS USED TO COMPARE NOMINAL THRUST TRACE, Figure 3.17.

(3) IMPULSE VALUES ARE CALCULATED FROM IGNITION.

TABLE 3.7 RSRM-13 THRUST IMBALANCE SUMMARY

	LIMIT	MAX IMBALANCE (KLBF)	TIME
STEADY STATE (1 SEC TO 79 SEC)	85 K	- 25.0	1.5 SEC
STEADY STATE 80 SEC TO FIRST WEB TIME MINUS 8.5 SEC	120 K	32.3	82
TRANSITION FIRST WEB TIME - 8.5 SEC TO FIRST WEB TIME	120 - 268 K LINEAR	38.9	101.5
TAILOFF FIRST WEB TIME MINUS LATEST ACTION	710	- 118.1	111.5

THRUST IMBALANCE = LEFT SRM - RIGHT SRM

TABLE 3.8
MATCHED PAIR PERFORMANCE LIMITS

PARAMETER	CEI SPECIFICATION MAX DIFFERENCE(%) (1)	DELIVERED % DIFFERENCE (2)
WEB TIME	±2.0	0.73
ACTION TIME	±3.0	0.30
WEB TIME AVG PRESSURE	±2.0	0.39
MAX PRESSURE	N/A	0.26
MAX SEA LEVEL THRUST	N/A	0.32
WEB TIME AVG VAC THRUST	±2.0	0.38
VAC DEL SPECIFIC IMPULSE	±1.0	0.01
WEB TIME VAC TOTAL IMPULSE	±1.4	0.34
ACTION TIME TOTAL IMPULSE	±1.4	0.02

PRESSURE VALUES IN PSIA, THRUST VALUES IN MLBF,
IMPULSE VALUES IN MLBF-SEC
TIME VALUES IN SECONDS

(1) CEI SPECIFICATION PARAGRAPH 3.2.1.1.2.2, TABLE II

(2) DIFFERENCE = ((RSRM-13A - RSRM-13B)/RSRM-13 AVERAGE)*100
DATA AT PMBT OF 82°F

TABLE 3.9

360Q013-LH SEQUENTIAL MASS PROPERTIES

EVENTS/TIMES	WEIGHT (LBS)	CENTER OF GRAVITY LONG.	LAT.	VERT.	MOMENT OF INERTIA PITCH	ROLL	YAW
PRE-LAUNCH TIME = 0.00	1257378.4	1171.267	0.059	0.006	42484.105	880.593	42484.981
LIFT-OFF TIME = 0.23	1256687.2	1171.398	0.059	0.006	42441.340	879.212	42442.216
INTERMEDIATE BURN TIME = 20.00	1011522.1	1208.712	0.074	0.007	30587.166	760.162	30588.040
INTERMEDIATE BURN TIME = 40.00	790154.3	1231.603	0.094	0.009	21598.327	625.271	21599.194
MAX "Q" TIME = 54.00	659731.3	1228.956	0.112	0.011	17923.754	547.753	17924.615
INTERMEDIATE BURN TIME = 60.00	604187.9	1226.299	0.121	0.012	16490.616	509.956	16491.474
INTERMEDIATE BURN TIME = 80.00	409794.5	1214.448	0.177	0.018	11772.762	374.327	11773.608
MAX "G" TIME = 87.00	345367.1	1214.105	0.210	0.022	10395.231	323.212	10396.074
INTERMEDIATE BURN TIME = 100.00	239192.1	1228.864	0.301	0.031	8397.801	233.184	8398.634
WEB BURN TIME = 109.42	175456.5	1265.405	0.408	0.043	7312.477	174.505	7313.303
END OF ACTION TIME TIME = 121.46	145009.7	1314.151	0.492	0.052	6595.511	147.112	6596.333
SEPARATION TIME = 123.84	144382.9	1316.216	0.494	0.052	6562.301	146.662	6563.125
MAX REENTRY "Q" TIME = 318.84	143889.3	1316.054	0.495	0.051	6541.192	146.233	6542.018
NOSE CAP DEPLOYMENT TIME = 348.84	143837.1	1316.035	0.495	0.051	6538.429	146.187	6539.255
DROGUE CHUTE DEPLOYMENT TIME = 349.44	143836.1	1316.035	0.495	0.051	6538.374	146.186	6539.200
FRUSTUM RELEASE TIME = 370.54	143799.4	1316.022	0.496	0.051	6536.418	146.154	6537.244
MAIN CHUTE LINE STRETCH TIME = 371.84	143797.2	1316.021	0.496	0.051	6536.297	146.152	6537.122
MAIN CHUTE 1ST DISREEFING TIME = 381.94	143779.6	1316.015	0.496	0.051	6535.357	146.136	6536.183
MAIN CHUTE 2ND DISREEFING TIME = 387.84	143769.3	1316.011	0.496	0.051	6534.806	146.127	6535.633
NOZZLE JETTISONED TIME = 388.54	141540.0	1305.845	0.494	0.050	6339.759	141.617	6340.564
SPLASHDOWN TIME = 413.84	141496.0	1305.827	0.494	0.050	6337.382	141.578	6338.187

TABLE 3.10

360Q013-RH SEQUENTIAL MASS PROPERTIES

EVENTS/TIMES	WEIGHT (LBS)	CENTER OF GRAVITY LONG.	LAT.	VERT.	MOMENT OF INERTIA PITCH	ROLL	YAW
PRE-LAUNCH TIME = 0.00	1257278.5	1171.334	0.059	0.006	42483.835	880.512	42484.710
LIFT-OFF TIME = 0.23	1256579.5	1171.464	0.059	0.006	42440.899	879.138	42441.774
INTERMEDIATE BURN TIME = 20.00	1010606.7	1208.875	0.074	0.007	30545.524	759.601	30546.396
INTERMEDIATE BURN TIME = 40.00	788533.3	1231.637	0.094	0.010	21542.387	624.256	21543.254
MAX "Q" TIME = 54.00	657923.0	1228.860	0.112	0.011	17871.572	546.598	17872.432
INTERMEDIATE BURN TIME = 60.00	602426.3	1226.150	0.122	0.012	16437.368	508.527	16438.224
INTERMEDIATE BURN TIME = 80.00	408552.2	1214.252	0.178	0.018	11736.262	373.322	11737.107
MAX "G" TIME = 87.00	344646.5	1213.938	0.210	0.022	10371.591	322.596	10372.431
INTERMEDIATE BURN TIME = 100.00	239206.0	1228.539	0.300	0.031	8388.824	233.183	8389.656
WEB BURN TIME = 110.22	171714.8	1268.494	0.416	0.044	7233.178	171.018	7234.003
END OF ACTION TIME TIME = 121.84	144851.0	1313.800	0.492	0.052	6583.531	146.988	6584.352
SEPARATION TIME = 123.84	144312.5	1315.618	0.494	0.052	6549.476	146.603	6550.300
MAX REENTRY "Q" TIME = 318.84	143741.7	1315.685	0.495	0.051	6529.468	146.122	6530.294
NOSE CAP DEPLOYMENT TIME = 348.84	143689.6	1315.665	0.495	0.051	6526.705	146.076	6527.530
DROGUE CHUTE DEPLOYMENT TIME = 349.44	143688.5	1315.665	0.495	0.051	6526.650	146.075	6527.475
FRUSTUM RELEASE TIME = 370.54	143651.9	1315.651	0.496	0.051	6524.693	146.043	6525.518
MAIN CHUTE LINE STRETCH TIME = 371.84	143649.6	1315.651	0.496	0.051	6524.573	146.041	6525.398
MAIN CHUTE 1ST DISREEFING TIME = 381.94	143632.0	1315.644	0.496	0.051	6523.633	146.025	6524.458
MAIN CHUTE 2ND DISREEFING TIME = 387.84	143621.8	1315.641	0.496	0.051	6523.082	146.016	6523.907
NOZZLE JETTISONED TIME = 388.54	141392.4	1305.461	0.494	0.051	6327.701	141.505	6328.506
SPLASHDOWN TIME = 413.84	141348.5	1305.443	0.494	0.051	6325.324	141.466	6326.129

TABLE 3.11

SEQUENTIAL MASS PROPERTIES PREDICTED/ACTUAL COMPARISONS
3600013-LH

Event	Weight (lb)				Longitudinal CG (in)			
	Predicted[1]	Actual	Delta	% Error	Predicted[1]	Actual	Delta	% Error
Pre-Ignition	1,257,378	1,257,378	0	0.00	1,171.267	1,171.267	0.000	0.00
Liftoff	1,256,688	1,256,687	-1	0.00	1,171.399	1,171.398	-0.001	0.00
Action Time	144,857	145,010	+153	0.11	1,314.510	1,314.151	-0.359	0.03
Separation[2]	144,326	144,383	+57	0.04	1,316.103	1,316.216	+0.113	0.01
Nose Cap Deployment	143,837	143,837	0	0.00	1,316.042	1,316.035	-0.007	0.00
Drogue Chute Deployment	143,836	143,836	0	0.00	1,316.042	1,316.035	-0.007	0.00
Main Chute Line Stretch	143,797	143,797	0	0.00	1,316.028	1,316.021	-0.007	0.00
Main Chute 1st Disreefing	143,780	143,780	0	0.00	1,316.022	1,316.015	-0.007	0.00
Main Chute 2nd Disreefing	143,769	143,769	0	0.00	1,316.018	1,316.011	-0.007	0.00
Nozzle Jettison	141,540	141,540	0	0.00	1,305.845	1,305.845	0.000	0.00
Splash Down	141,496	141,496	0	0.00	1,305.827	1,305.827	0.000	0.00

Notes:

1. Based on Mass Properties History Log Space Shuttle 3600013-LH, 24 October 1990 (TWR-17358B).

2. The separation longitudinal center of gravity of 1,316.216 is 66% of the vehicle length.

TABLE 3.12

SEQUENTIAL MASS PROPERTIES PREDICTED/ACTUAL COMPARISONS
3600013-RH

Event	Weight (lb)				Longitudinal CG (in)			
	Predicted[1]	Actual	Delta	% Error	Predicted[1]	Actual	Delta	% Error
Pre-Ignition	1,257,279	1,257,279	0	0.00	1,171.334	1,171.334	0.000	0.00
Liftoff	1,256,588	1,256,580	-8	0.00	1,171.466	1,171.464	-0.002	0.00
Action Time	144,709	144,851	+142	0.10	1,314.141	1,313.800	-0.341	0.03
Separation[2]	144,179	144,313	+134	0.09	1,315.735	1,315.618	-0.117	0.01
Nose Cap Deployment	143,690	143,690	0	0.00	1,315.673	1,315.665	-0.008	0.00
Drogue Chute Deployment	143,688	143,688	0	0.00	1,315.673	1,315.665	-0.008	0.00
Main Chute Line Stretch	143,650	143,650	0	0.00	1,315.659	1,315.651	-0.008	0.00
Main Chute 1st Disreefing	143,632	143,632	0	0.00	1,315.653	1,315.644	-0.009	0.00
Main Chute 2nd Disreefing	143,622	143,622	0	0.00	1,315.649	1,315.641	-0.008	0.00
Nozzle Jettison	141,393	141,392	-1	0.00	1,305.461	1,305.461	0.000	0.00
Splash Down	141,349	141,349	0	0.00	1,305.443	1,305.443	0.000	0.00

Notes:

1. Based on Mass Properties History Log Space Shuttle 3600013-RH, 24 October 1990 (TWR-17359A).

2. The separation longitudinal center of gravity of 1,315.618 is 66% of the vehicle length.

TABLE 3.13

PREDICTED/ACTUAL WEIGHT (lb) COMPARISONS

3600013-LH

Item	Minimum	Maximum	Predicted[3]	Actual	Delta	% Error	Notes
Inerts							
Prefire, Controlled		151,380	150,105	150,105	0	0.00	1
Propellant	1,103,730		1,107,274	1,107,274	0	0.00	1
Usable			1,106,358	1,106,558	+200	0.02	2
To Liftoff			592	593	+1	0.17	
Liftoff to Action			1,105,766	1,105,965	+199	0.02	2
Unusable			916	716	-200	27.93	
Action to Separation			818	561	-257	45.81	
After Separation			98	155	+57	36.77	
Slag			2,000	2,000	0	0.00	2

Notes:

1. Requirement per CPW1-3600A, Addendum G, Part I, (RSRM CEI Specification).
2. Slag included in usable propellant, liftoff to action.
3. Based on 24 October 1990, Mass Properties History Log Space Shuttle 3600013-LH (TWR-17358B).

TABLE 3.14

PREDICTED/ACTUAL WEIGHT (lb) COMPARISONS

3600013-RH

Item	Minimum	Maximum	Predicted[3]	Actual	Delta	% Error	Notes
Inerts							
Prefire, Controlled		151,380	149,959	149,959	0	0.00	1
Propellant	1,103,730		1,107,320	1,107,320	0	0.00	1
Usable			1,106,404	1,105,615	+211	0.02	2
To Liftoff			592	601	9	1.50	
Liftoff to Action			1,105,812	1,106,014	+202	0.02	2
Unusable			916	705	-211	29.93	
Action to Separation			818	473	-345	72.94	
After Separation			98	232	+134	57.76	
Slag			2,000	2,000	0	0.00	2

Notes:

1. Requirement per CPW1-3600A, Addendum G, Part I, (RSRM CEI Specification).
2. Slag included in usable propellant, liftoff to action.
3. Based on 24 October 1990, Mass Properties History Log Space Shuttle 3600013-RH (TWR-17359A).

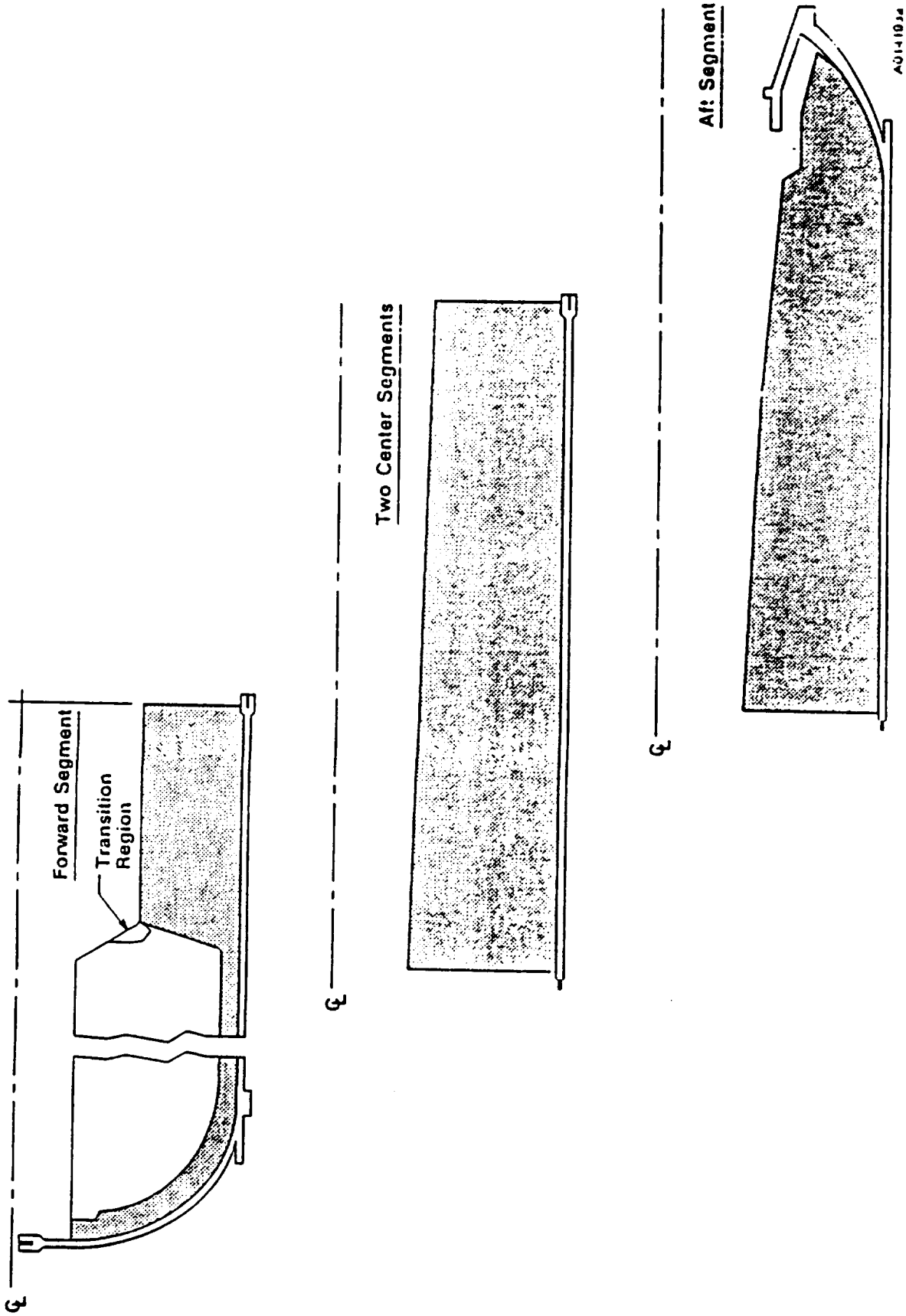

Figure 1.1 RSRM Propellant Grain Design Configuration

Figure 2.1
RSRM-13 Reconstructed Vacuum Thrust vs. Time
at Delivered Conditions (80 Deg. F)

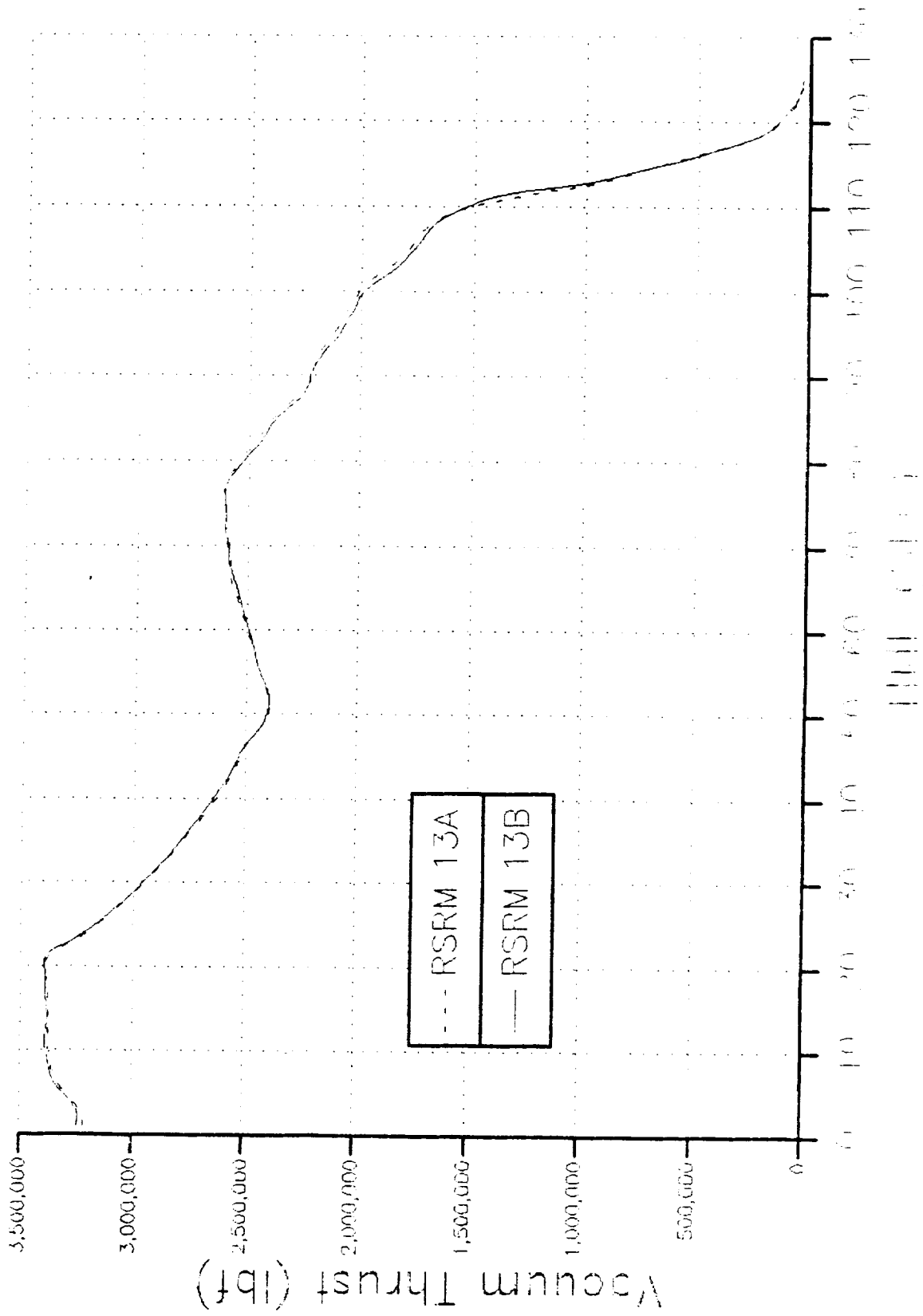

Figure 3.1
RSRM-13A Predicted vs. Reconstructed
Vacuum Thrust at 82 Deg. F

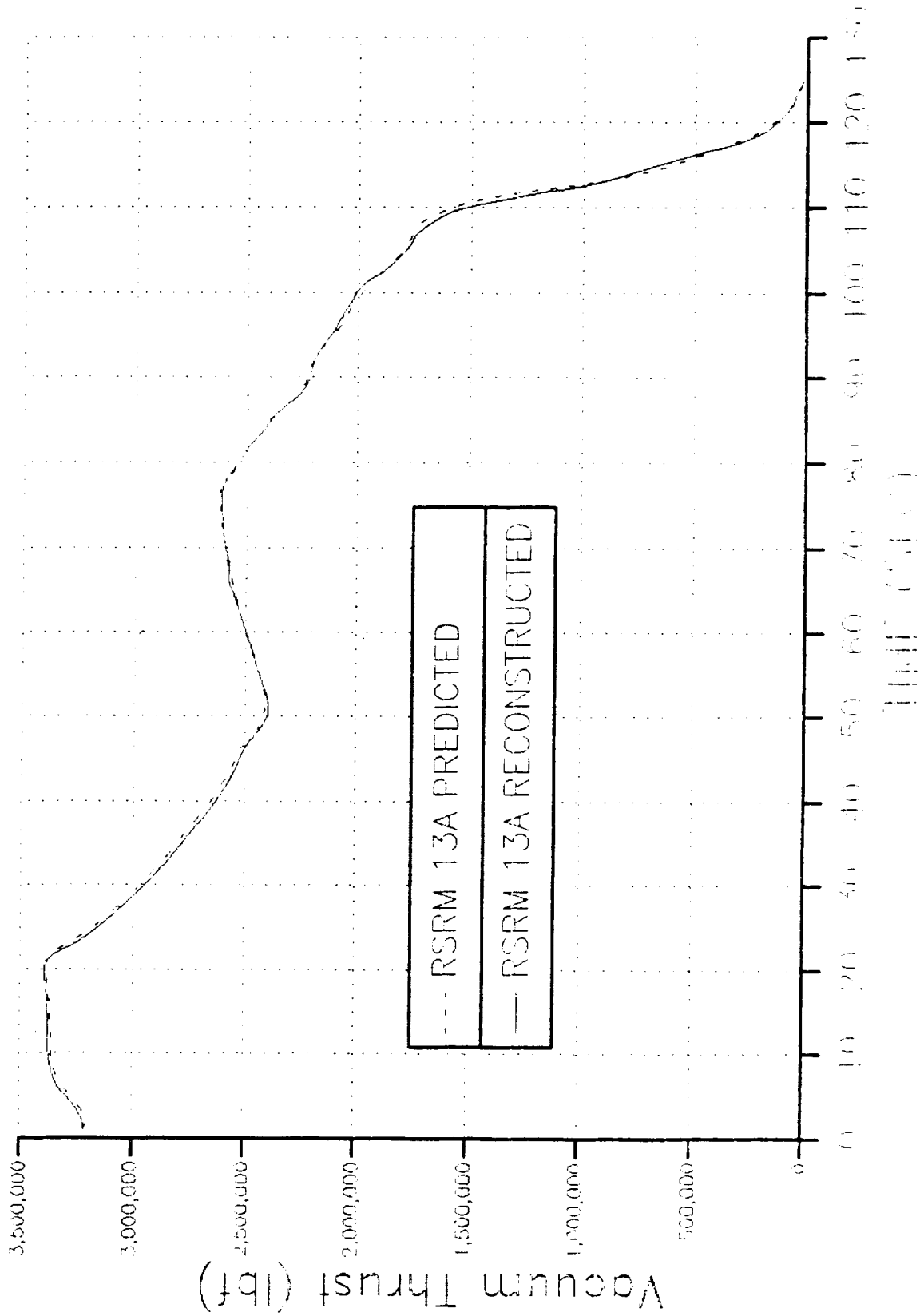

Figure 3.4-1
RSRM-13B Predicted vs. Reconstructed
Vacuum Thrust at 82 Deg. F

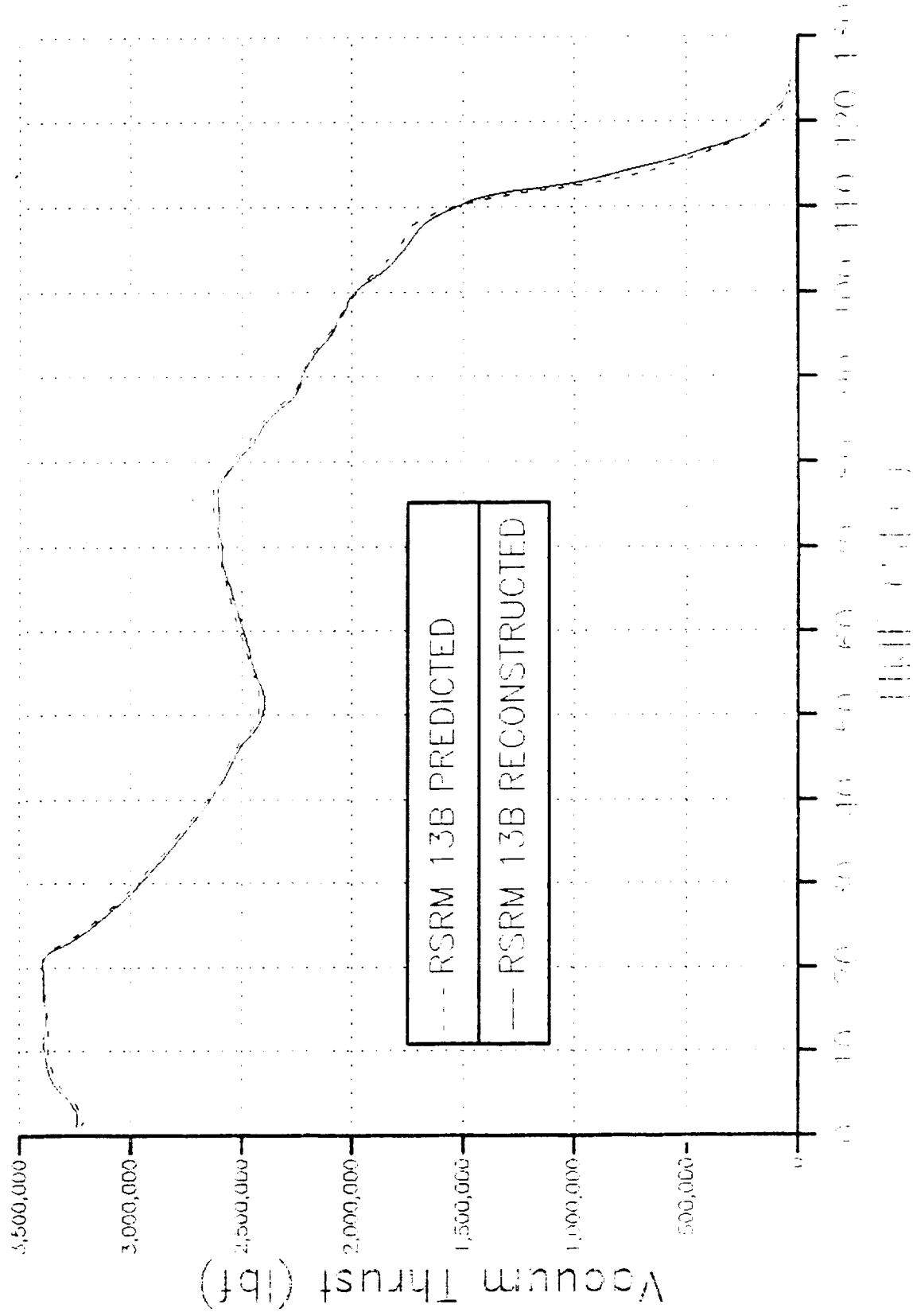

Figure 3.1.3
RSRM-13A Predicted vs. Measured
Chamber Pressure at 82 deg F

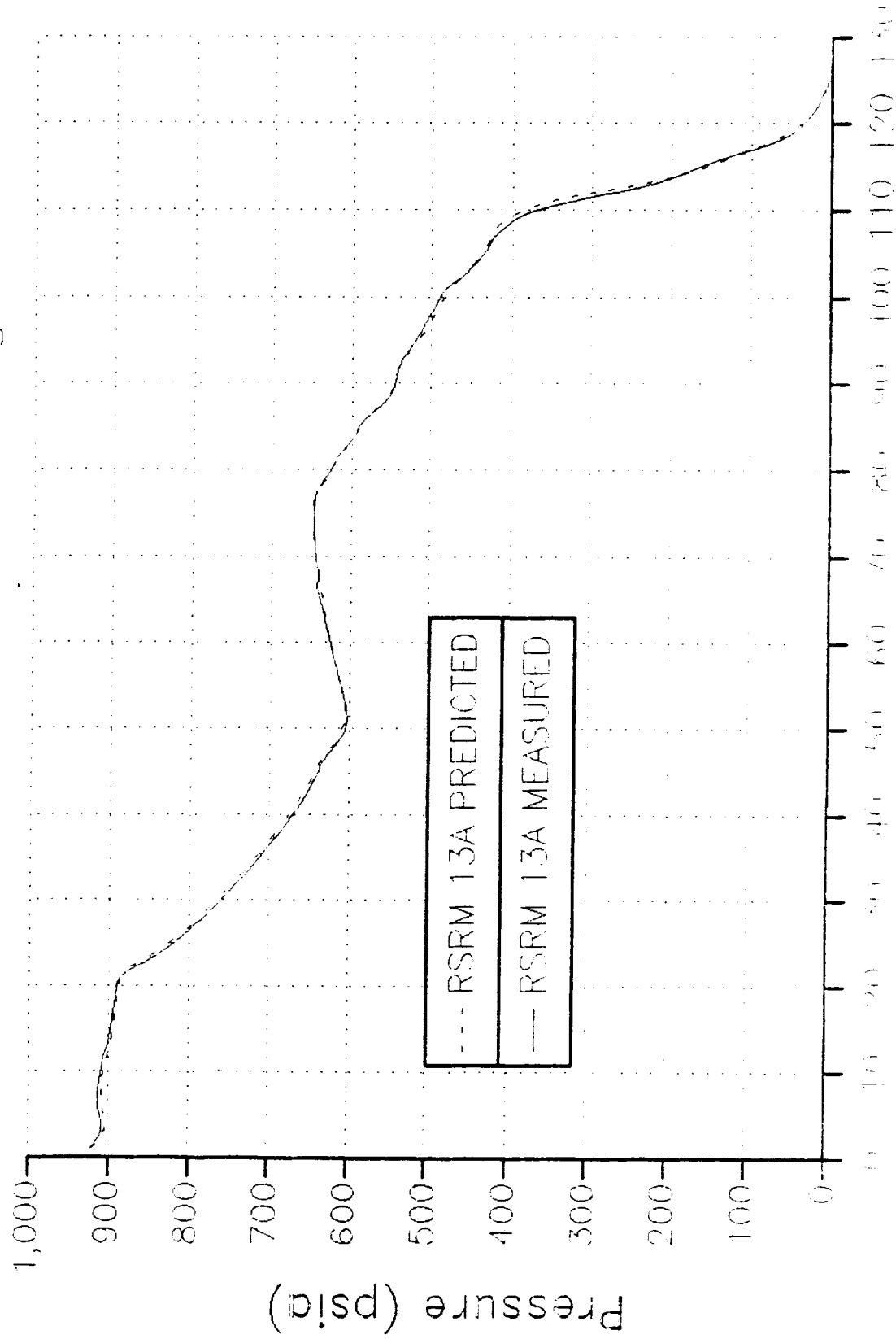

Figure 3.4
RSRM-13B Predicted vs. Measured
Chamber Pressure at 82 deg F

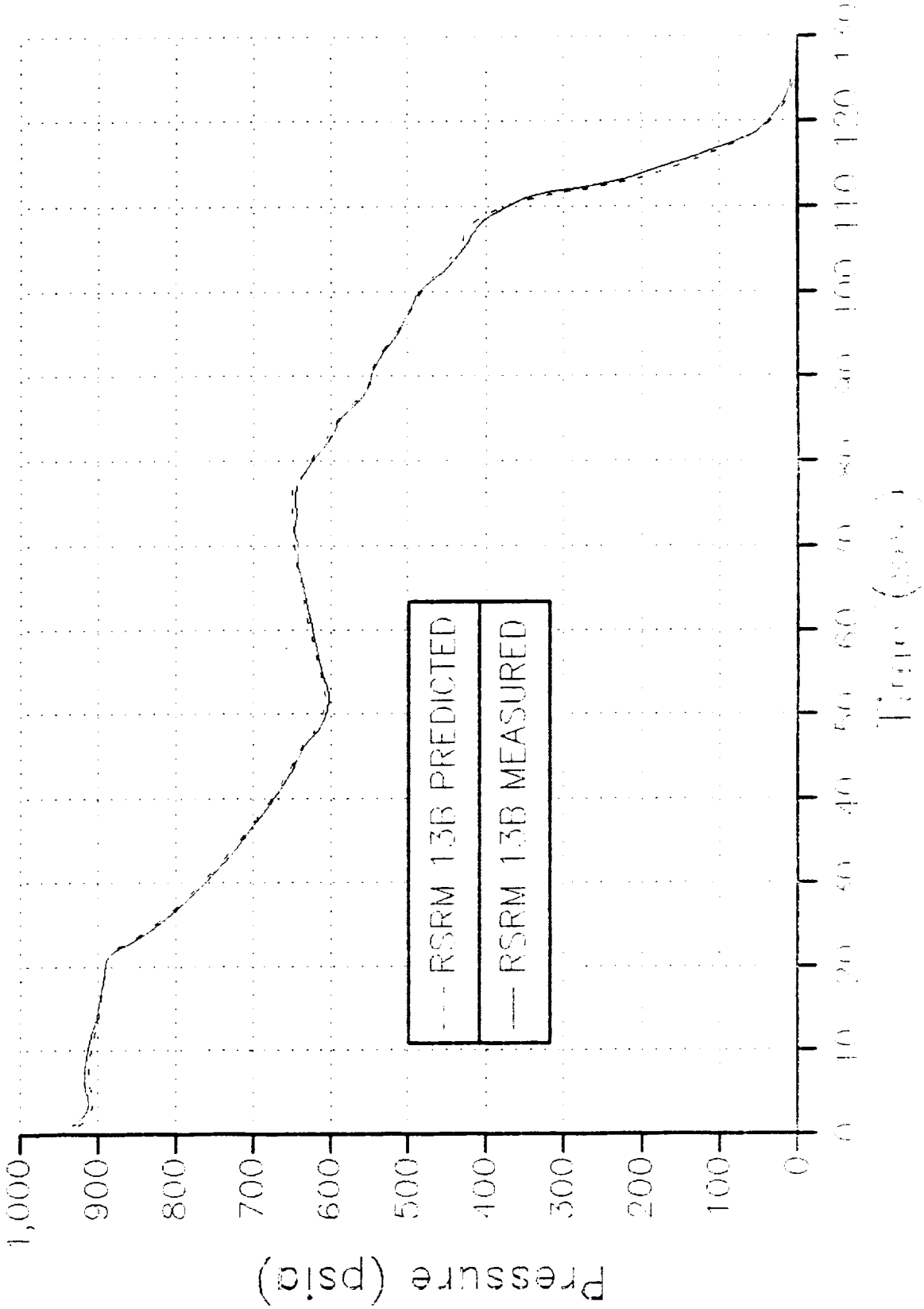

Figure 3.5-b
RSRM-13A Performance Compared to
RSRM Population Nominal

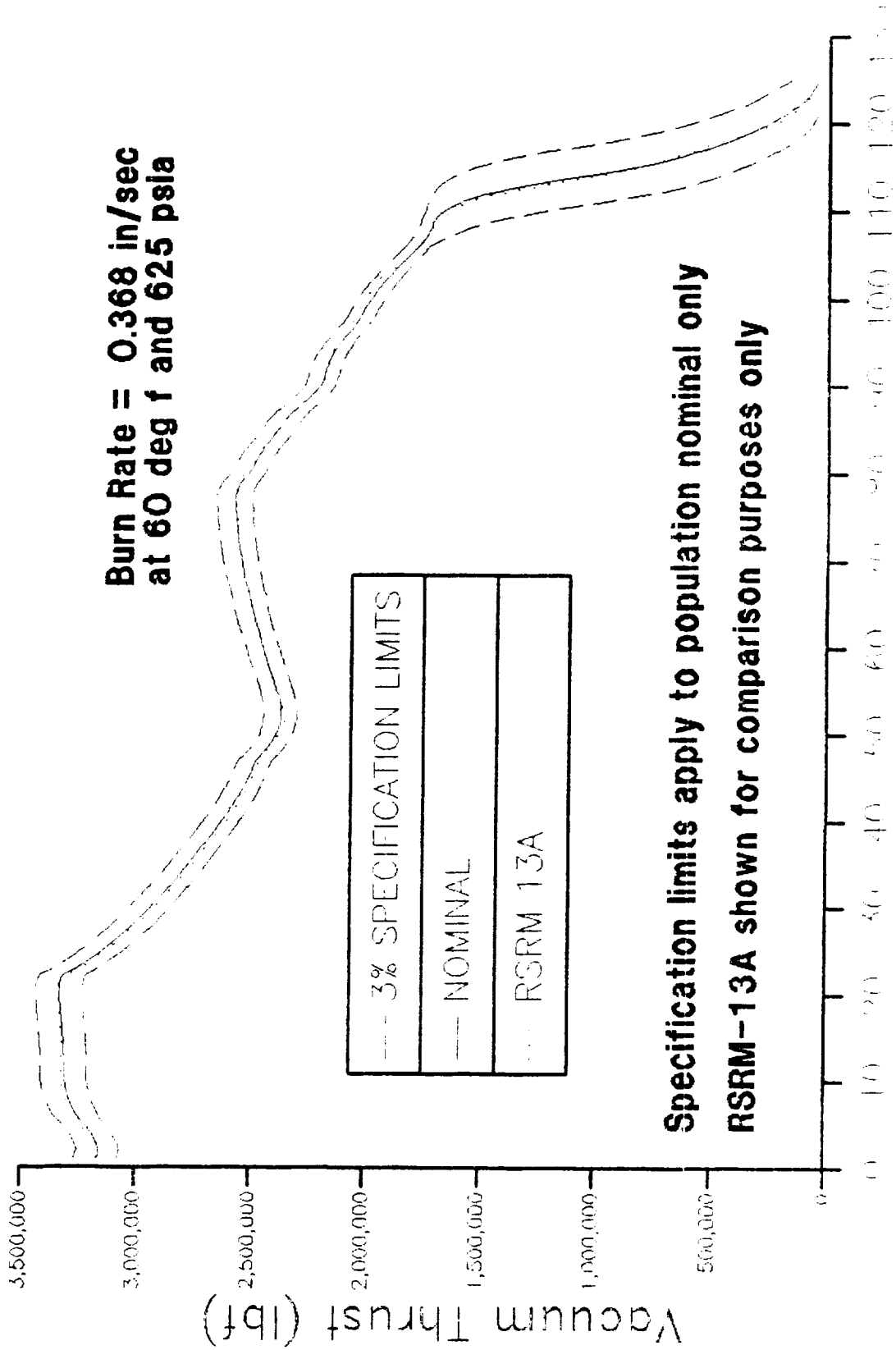

Figure 3.6
RSRM-13B Performance Compared to
RSRM Population Nominal

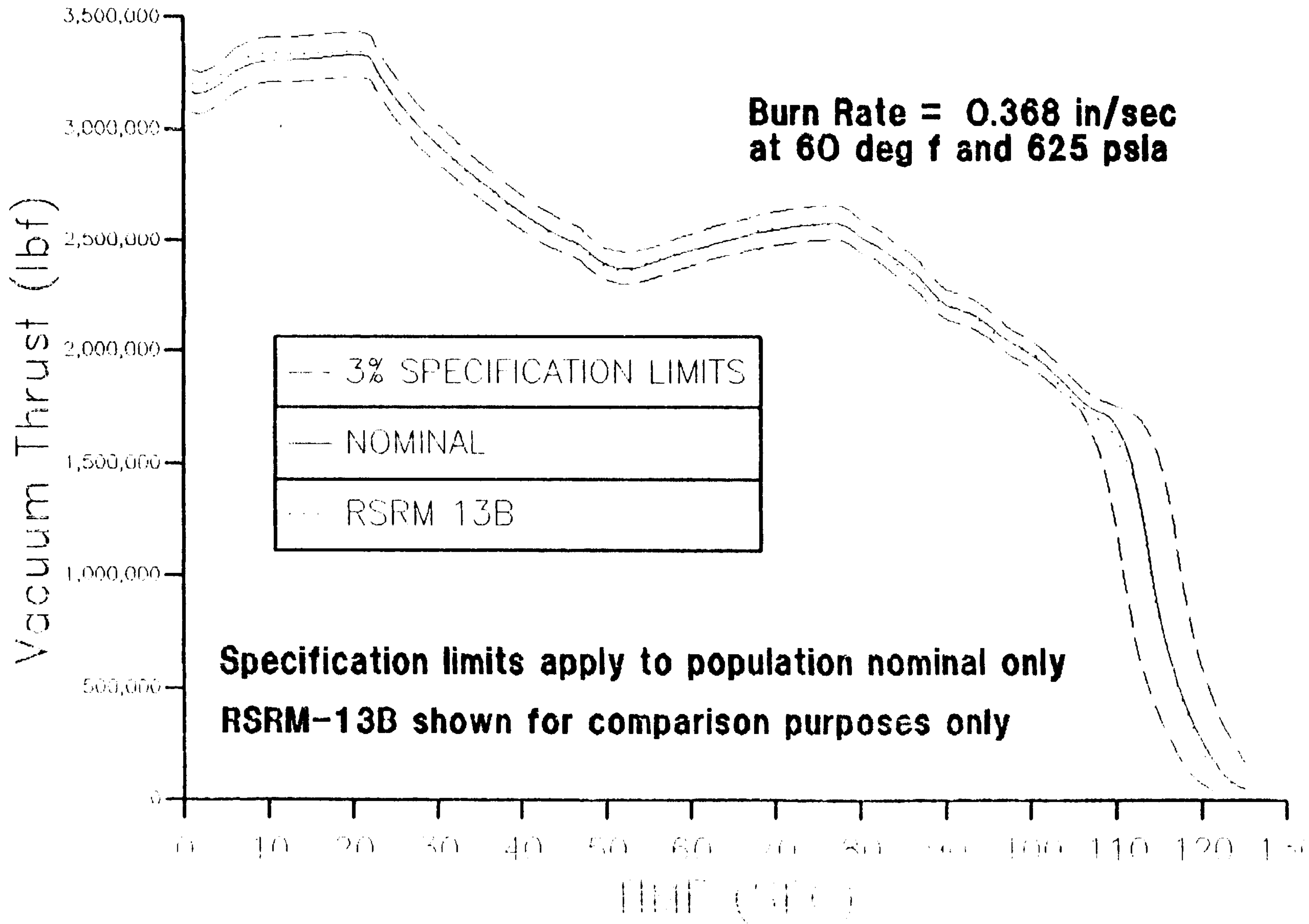

Figure 3.7

RSRM Nominal Performance Compared
to CEI CPW1-3600A Specification Limits

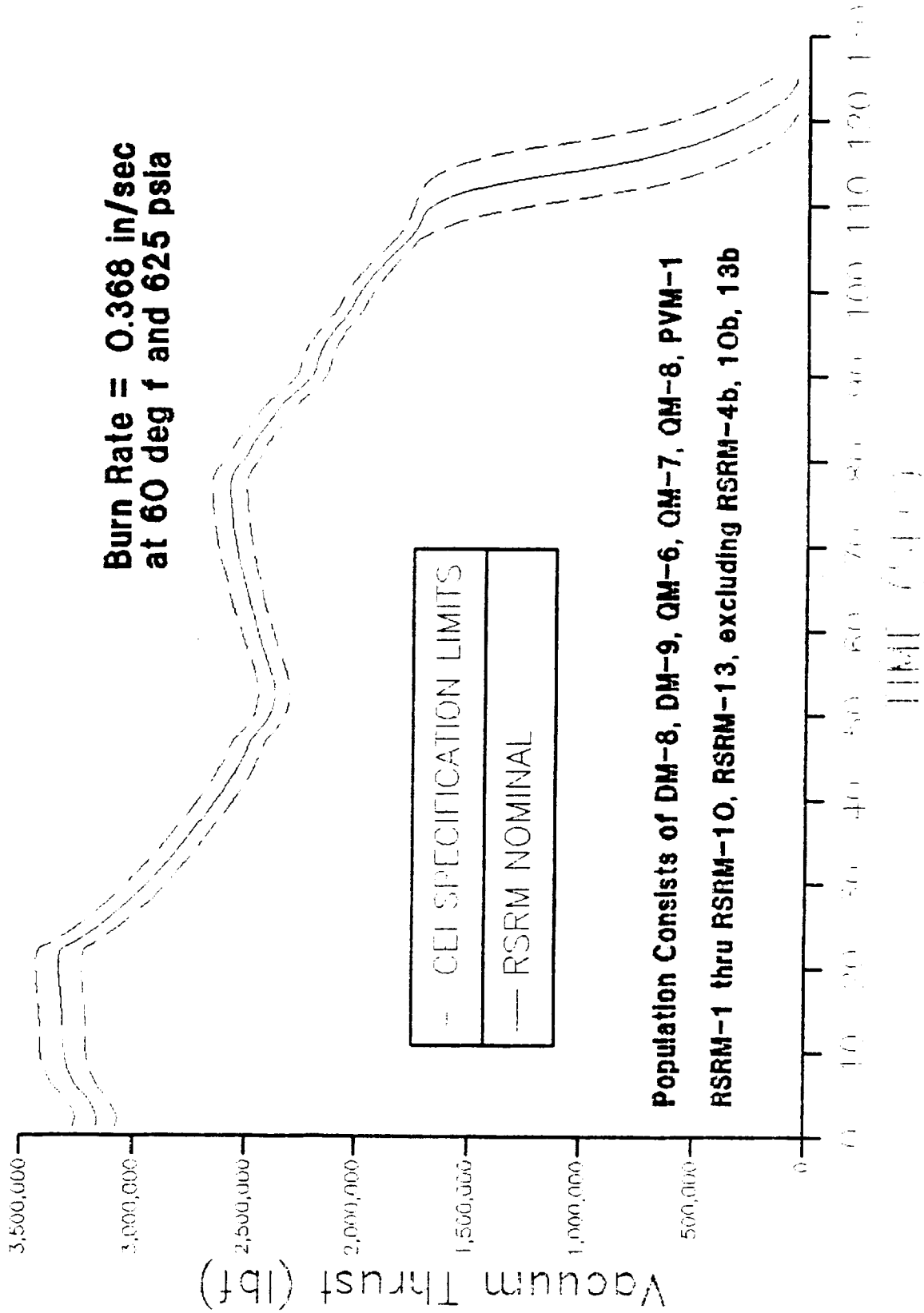

Figure 3.8
RSRM-13 Instantaneous
Steady State Thrust Imbalance
Left minus Right